

SUBJECT: A Compilation of Discharged Fluids
and Fluid Vent Properties for the
AAP Cluster - Case 620

DATE: June 30, 1969

FROM: J. J. Sakolosky

MEMORANDUM FOR FILE

A number of studies have been performed to determine the contaminating effects of various types of overboard fluid discharges on exposed Cluster surfaces. Work is continuing in this area in an effort to quantify the effects of various sources. In addition, there is a need to identify all of the possible sources of contamination associated with the AAP missions. The purpose of this memorandum is to provide a comprehensive listing of AAP Cluster contamination sources, source locations, and the quantity of potential contaminant discharged from each location. Primary emphasis was placed on fluids discharged from the Cluster while in the docked configuration. Although contamination sources exist on each module while in the undocked mode, the quantity of potential contaminating fluids emitted in this mode is small compared to that in the docked configuration. An effort was made to obtain information on the physical configuration, flow characteristics, and location of the vents and nozzles from which the major contaminants are discharged.

EFFECTS OF LIQUID AND GAS VENTING*

There are many contamination sources inherent to the AAP Cluster. Spacecraft atmospheric leakage, waste materials venting, molecular sieve regeneration, SM RCS and WACS thruster exhaust products, EVA activities, and materials outgassing are some examples of these sources. The degenerative effects of each of these sources vary, and in all cases they are difficult to quantify. However, qualitative information on relative source effects is available and will be discussed briefly below.

The immediate effect of fluid discharges from the AAP modules will be to create an artificial atmosphere in the vicinity of the Cluster. Liquid venting and molecular sieve

* An extension of the information contained in this section is available in Reference 4.

regeneration (water and CO₂ dumping) are potentially the most harmful sources with respect to optical experiments since considerable light scattering could result from ice particles formed during the dump. However, problems resulting from liquid venting can probably be avoided by programming liquid discharges to occur on the dark side of the orbit. Atmospheric drag will then act as a clearing force to remove any ice particles generated during the dump from the vicinity of the Cluster by the time the light side of the orbit is reached. The molecular sieve will pose a more formidable problem in this respect since regenerative venting to space vacuum occurs continuously throughout the orbit. RCS and WACS thruster burns will contribute only extremely transient effects to cloud formation since their exhaust velocities are high (up to 12,000 ft/sec).

The long-term effect of this tenuous atmosphere surrounding the Cluster will be a gradual, but cumulative, surface deposition process. Thermal control coatings, spacecraft windows, optical surfaces, and Cluster solar array performance could all be adversely affected by this phenomenon. Although venting of urine and water on the dark side of the orbit will eliminate interference with the optical experiments, it will not solve the surface contamination problem. Ice particles formed during the dump may collect on a surface and act as trapping centers for other contaminants, or they may be jarred from the surface at some later time in the mission. An equally serious source of concern is plume impingement from the SM RCS and WACS thrusters on exposed Cluster surfaces. Significant surface deposits of unreacted propellants and exhaust products may result, particularly during pulsed thruster operation (burn times on the order of msec's). Molecular sieve venting may also cause serious degradation of exposed surfaces, but contact area is expected to be small. Other sources contributing to possible surface contamination are EVA activity, materials outgassing, and atmospheric leakage.

The venting of fluids and gases from the AAP spacecraft may also have significant impact on the Cluster attitude control system. Most of the liquid and gas vents for the AAP Cluster are propulsive, and the possibility exists that some of these may result in significant disturbing torques. According to a previous work (Ref. 1), approximately 135 lbs of WACS propellant may be required to counteract these torques for the three AAP missions.

CLUSTER VENTING SOURCES

A number of assumptions were made in determining the quantity of fluids dumped from the Cluster. Man's daily water balance and the fuel cell operating power levels are listed in Table I. Metabolic CO₂ production was assumed to be

2.25 lbs/man/day. Other relevant assumptions made in determining fluid quantities discharged from the Cluster appear as footnotes in Table II, which lists the quantity and kinds of fluids discharged from the various AAP spacecraft. Overboard dump and vent quantities are given on a lbs/day basis (where applicable) and also on a pounds per mission basis. The data of Table II are summarized in Table IIIA and Table IIIB. Table IIIA provides a summary of the total fluids discharged from the Cluster grouped according to contamination source (e.g., atmospheric leakage, EVA activity, molecular sieve, etc.). This summary is provided for each AAP mission. Table IIIB provides a summary of the same data tabulated in a different manner. Total fluids discharged from the Cluster are grouped according to type (e.g., carbon dioxide, nitrogen, water, urine, etc.). Once again totals are presented on a mission basis. Table IV presents the totals for each AAP spacecraft.

Table V and Figure 1 combine to provide a description of the AAP Cluster liquid and gas overboard vents. Information has been included in Table V on vent sizes and discharge flow rates if this information is available. Figure 1 illustrates vent locations for each of the AAP spacecraft. Discharge velocity vector directions are also shown.

DISCUSSION

Table III indicates that the 1658 pounds of liquid dumped from the Cluster for each of the 56-day missions is almost equally divided between urine, humidity condensate, and excess fuel cell water. The ratio of excess fuel cell water is greater for AAP-1/AAP-2 since the CM fuel cells are operated at a higher power level. All of the urine dumped overboard for the three missions is assumed to be discharged non-propulsively from the OWS into the LOX tank. This can be expected to freeze within the network of baffles in the LOX tank, and therefore should not contribute significantly to surface contamination of the Cluster. All of the humidity condensate discharged overboard (after AM activation) for the three missions will be from the AM/STS dump nozzle.

As of this time no hard restrictions have been formulated with respect to allowable liquid dumping times from the Cluster. As a result no dumping timeline exists. However, an effort is being made to design a 24-hour water hold capability into the CM so that liquids will not be discharged during critical experiment periods.

The weight of gaseous fluids discharged from the Cluster ranges from 911 lbs for AAP-1/AAP-2 to 2340 lbs for AAP-3/AAP-4. AAP-3A vents a total of 1756 lbs of gases overboard.

For each mission the major source of discharged gases is atmospheric leakage, accounting for from 40% to 50% of the total. Oxygen and nitrogen are the primary atmospheric gases leaked from the Cluster although water vapor, carbon dioxide, and various other trace gases will also be present in smaller amounts. Atmospheric leakage will occur primarily in the vicinity of structural joints and at docked interfaces. For the Cluster this means that over half (approx. 11 lbs/day) of the 20 lbs/day atmospheric leakage during AAP-3/AAP-4 will occur in the area of the LM and MDA. LM leakage is presently specified as 4.8 lbs/day, and leakage from the docking ports and the MDA will add another 6.2 lbs/day to this number. The remaining 9 lbs/day of Cluster atmospheric leakage are distributed among the CM, AM, and the OWS.

The second largest source of gases discharged from the Cluster is the molecular sieve. Carbon dioxide, water vapor, and oxygen are the primary gases discharged from the sieve. This discharge occurs continuously and non-propulsively from the structural transtion section. Approximately 13.6 lbs/day of gas are discharged to space. On AAP-3/AAP-4, EVA activity accounts for over 300 lbs of gases being discharged in the vicinity of LM/ATM surfaces. These gases will consist primarily of oxygen and water vapor with some nitrogen and carbon dioxide also being present.

For the three AAP missions, oxygen accounts for approximately 40% to 50% of the gases discharged overboard. Nitrogen accounts for another 12% of the total. The remaining gases are almost equally divided between water vapor and carbon dioxide; small amounts of trace gases also appear as a result of materials outgassing and metabolic processes.

Total budgeted RCS and WACS fuel for use during docked (and docking) operations is 2174 lbs, a potentially prodigious source of surface contamination from plume impingement. From Table III it can be seen that missions AAP-1/AAP-2 and AAP-3A account for 1850 lbs of this total. AAP-3/AAP-4, which utilizes the ATM control moment gyros for attitude control purposes, contributes the remaining 324 lbs. These budgeted numbers for RCS and WACS fuel consumption provide an overly pessimistic estimate of exhaust products emitted during the docked configuration. Approximately 483 pounds of the CM RCS budgeted fuel for AAP-1/AAP-2 is used to initially circularize the Cluster orbit.

This burn is directed along the +X axis of the OA and is not likely to contribute significantly to contamination of Cluster surfaces. In addition about 75% of the fuel (~150 lbs) budgeted to the SM RCS for AAP-3/AAP-4 will be used only in a back-up mode for desaturating the ATM control moment gyros.

Surface contamination resulting from plume impingement will be most severe in the case of pulsed thruster operation. This is the mode of operation that the WACS will utilize (50-60 msec. burn times). The SM RCS burn times will range from milliseconds to seconds depending on the particular maneuver being accomplished.

SUMMARY

Approximately 5-3/4 tons of potential contaminating gases and liquids will be discharged from the AAP Cluster over its lifetime. This amounts to an average discharge rate of 6.9 lbs/orbit for AAP-1/AAP-2, 4.9 lbs/orbit for AAP-3A, and 5.0 lbs/orbit for AAP-3/AAP-4. Precise quantitative knowledge of the effects these discharged fluids will have on the AAP Cluster performance is lacking, but the sheer magnitude of the numbers involved implies that the effects may be significant. Particularly critical is the prospect of severe surface contamination occurring from the continuous contact of exposed Cluster surfaces to the artificial atmosphere generated in the vicinity of the Cluster.

It is convenient to classify the emitted products of the Cluster into two general categories -- those which are vented continuously and those which are vented intermittently. It should be possible to exercise some degree of control over some of the intermittently vented products so as to minimize their possibly harmful effects on Cluster operations.

The continuously emitted products are atmospheric leakage, materials outgassing, and gases vented from the molecular sieve. Of these, molecular sieve venting can be controlled to the extent of location and direction of the emitted stream.

Some of the intermittently discharged fluids from the Cluster result from urine and condensate dumps, EVA activity, RCS and WACS burns, feces and urine drying, scientific airlock depressurizations, and the Lower Body Negative Pressure (LBNP) experiment. Of these, the most difficult to exert any

significant amount of control over is probably the RCS and WACS burns which, unfortunately, may prove to be a severe source of contamination to impinged surfaces.

Only two of the vents used for discharging Cluster waste materials during the docked mission are non-propulsive. They are the molecular sieve vent and the SIVB LOX tank passivation vent which is later used in conjunction with urine dumping. In addition, the waste management/LBNP vent in the MDA (used prior to OWS activation) has its velocity vector directed approximately through the Cluster center of gravity in an effort to minimize attitude disturbing torques.

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Table IA. MAN'S DAILY WATER BALANCE

<u>Input</u>	<u>lbs/man/day</u>	<u>Output</u>	<u>lbs/man/day</u>
Drinking and Food Rehydration	7.77	Urine*	3.30
Water in Food	.23	Fecal Water**	.25
Metabolic Water	.72	Transpired Water	5.17
	<u>8.72</u>		<u>8.72</u>
Personal Hygiene	2.00	Personal Hygiene	2.00

* 10%/man/day assumed to be dried for earth return.

** 93% of fecal water assumed to be removed during drying.

Table IB. CM FUEL CELL OPERATING POWER LEVELS

<u>Mission</u>	<u>Power Level</u>
AAP-1/AAP-2	2250 W
AAP-3A	1800 W
AAP-3/AAP-4	1800 W

Table II. AAP CLUSTER OVERBOARD DUMP AND VENT QUANTITIES

COMMAND MODULE	AAP-1/AAP-2		AAP-3A		AAP-3/AAP-4	
	lbs/day	mission	lbs/day	mission	lbs/day	mission
Urine Dump		All urine				
Waste Water Dump*	19.2	537.6	10.5	assumed to be dumped from OWS	10.5	588.0
Atmospheric Leakage	3.6	101.0	3.6	202.0	3.6	202.0
Vacuum Cleaner		Assumed	to	be	negligible	
Waste Stowage Vent		Assumed	to	be	negligible	
Water Boiler		Assumed	to	be	negligible	
SERVICE MODULE						
Fuel Cell O ₂ Purge	---	3.6	---	5.8	---	5.8
Fuel Cell H ₂ Purge	---	0.5	---	0.8	---	0.8
Fuel Cell Steam Vent		Assumed	to	be	negligible	

* Assumes excess fuel cell water dumped from CM

Table II. AAP CLUSTER OVERBOARD DUMP AND VENT QUANTITIES

SERVICE MODULE	AAP-1/AAP-2		AAP-3A		AAP-3/AAP-4	
	lbs/day	mission	lbs/day	mission	lbs/day	mission
Cryogenic O ₂ Vent		Assumed	to	be	negligible	
Cryogenic H ₂ Vent		Assumed	to	be	negligible	
RCS Burns	---	740.5	---	385.5	---	192.5
MULTIPLE DOCKING ADAPTER						
Fecal Dryer*	0.7	4.9	-----	not applicable	-----	
Urine Dryer*	1.0	7.0	-----	not applicable	-----	
LBNP Vacuum Source**	---	9.6	-----	not applicable	-----	
Atmospheric Leakage	2.6	73.0	2.6	146.0	2.6	146.0

* Assumes 7 days of operation in MDA before OWS activation

** Estimate based on two experiment periods per crew member before OWS activation,
Overboard Leakage rate assumed to be 100 liters/min @ 5 psi, LBNP device volume = 20 ft³.

Table II. AAP CLUSTER OVERBOARD DUMP AND VENT QUANTITIES

AIRLOCK/STS	AAP-1/AAP-2		AAP-3A		AAP-3/AAP-4	
	lbs/day	mission	lbs/day	mission	lbs/day	mission
Condensate Dump	10.1	282.8	10.1	566.0	10.1	566.0
Atmospheric Leakage	2.8	79.0	2.8	157.0	2.8	157.0
Scientific Airlock*		Assumed	to	be	negligible	
Molecular Sieve	13.6	380.8	13.6	761.0	13.6	761.0
Water Vapor	5.1	142.8	5.1	285.0	5.1	285.0
CO ₂	6.0	168.0	6.0	336.0	6.0	336.0
O ₂	1.9	53.2	1.9	106.4	1.9	106.4
N ₂	0.6	16.8	0.6	33.6	0.6	33.6
EVA Open Loop Gas Flow**	---	56.3	---	56.3	---	not applicable---
EVA Airlock Depressurization**	---	4.2	---	4.2	---	not applicable---

* Less than 1 ft.³ @ 5 psi dumped per cycle

** Based on one 2-man, 3-hour EVA per mission

Table II. AAP CLUSTER OVERBOARD DUMP AND VENT QUANTITIES

ORBITAL WORKSHOP	AAP-1/AAP-2		AAP-3A		AAP-3/AAP-4	
	lbs/day	mission	lbs/day	mission	lbs/day	mission
Fecal Dryer	0.7	14.7	0.7	39.2	0.7	39.2
Urine Dryer	1.0	21.0	1.0	56.0	1.0	56.0
Interim Urine Dump*	9.0	27.0	-----not applicable-----	-----not applicable-----	-----not applicable-----	-----not applicable-----
LOX tank Urine Dump*	9.0	224.0	9.0	504.0	9.0	504.0
Atmospheric Leakage	5.0	140.0	5.0	280.0	5.0	280.0
LBNP Vacuum Source**	---	14.4	---	48.0	---	48.0
WACS Burns	---	280.4	---	443.0	---	56.4
LUNAR MODULE						
Atmospheric Leakage	-----not applicable-----	-----not applicable-----	6.0	336.0		
EVA LM Depressurization	-----not applicable-----	-----not applicable-----	8.0/EVA	32.0		
EVA Open Loop Gas Flow***	-----not applicable-----	-----not applicable-----	56.3/EVA	225.1		
LCG Evaporators***	-----not applicable-----	-----not applicable-----	11.6/EVA	46.4		
RCS Helium Dump	-----not applicable-----	-----not applicable-----	---	4.4		

* Based on use of interim dump for 3 days before vent into LOX tank is installed.

** Estimate based on 3 experiment periods per astronaut on AAP-1/AAP-2; 10 experiment periods per astronaut on AAP-3A and AAP-3/AAP-4.

*** Based on four 2-man, 3-hour EVA's at a metabolic level of 2000 BTU/hr/man.

Table III A. SOURCE SUMMARY OF AAP CLUSTER DISCHARGED FLUIDS

	AAP-1/AAP-2	AAP-3A	AAP-3/AAP-4
Total Liquids	1072 lbs	1658 lbs	1658 lbs
Condensate	283	566	566
Urine	251	504	504
Excess Fuel Cell Water	538	588	588
Total Gases	911 lbs	1756 lbs	2340 lbs
Atmos. Leakage	393	785	1121
Molecular Sieve	381	761	761
EVA	61	61	304
Urine & Feces Drying	48	95	95
Other	28	54	59
Total Fuel Products	1021 lbs	829 lbs	324 lbs
OWS WACS	280	443	56
SM RCS	741	386	193
LM/ATM RCS	---	---	75

Table III B. SUMMARY OF AAP CLUSTER LIQUIDS AND GASES DISCHARGED TO SPACE

	AAP-1/AAP-2			AAP-3A		AAP-3/AAP-4	
Total Liquids	1072 lbs			1658 lbs		1658 lbs	
Water	821			1154		1154	
Urine	251			504		504	
Total Gases	911 lbs			1756 lbs		2341 lbs	
Oxygen	414			767		1192	
Nitrogen	111			221		303	
Carbon Dioxide	186			370		392	
Water Vapor	199			397		449	
Hydrogen	1			1		1	
Helium	---			---		4	
Thruster Exhaust Products	1021 lbs			829 lbs		324 lbs	
SM RCS	741			386		193	
OWS WACS	280			443		56	
LM/ATM RCS	---			---		75	

Table IV. AAP SPACECRAFT EFFLUENTS, LBS.

SPACECRAFT	AAP-1/AAP-2	AAP-3A	AAP-3/AAP-4	TOTAL
Command Module	639	790	790	2680
Service Module	744	392	199	1335
Multiple Docking Adapter	95	146	146	387
Airlock/STS	803	1545	1484	3832
Orbital Workshop	722	1370	984	2615
Lunar Module	---	---	644	644
TOTAL:	3003	4243	4247	11493 lbs

Table V. AAP MODULE LIQUID AND GAS OVERBOARD VENTS*

DESCRIPTION		LOCATION
Urine Dump	propulsive, .055" orifice, 1.25 lb/min, $\Delta P=5\text{psi}^5$	SIVB Sta.2172; Section D-D ² , Fig. 1
Waste Water Dump	propulsive, .055" orifice, 1.25 lb/min, $\Delta P=5\text{psi}^5$	SIVB Sta.2172, Section D-D ² , Fig. 1
Water Boiler	propulsive, 2.5" dia.	SIVB Sta.2170, Section E-E ² , Fig. 1
Waste Stowage Vent	propulsive, .055" orifice, .4 cfm ⁵	SIVB Sta.2172, Section E-E ⁵ , Fig. 1
Vacuum Cleaner	propulsive, .055" orifice, .4 cfm ⁵	SIVB Sta.2172, Section D-D ⁵ , Fig. 1
SERVICE MODULE		
Fuel Cell O ₂ Purge	propulsive,	SIVB Sta.2255, Section A-A ¹¹ , Fig. 1
Fuel Cell H ₂ Vent	propulsive,	SIVB Sta.2212, Section C-C ¹¹ , Fig. 1
Fuel Cell Steam Vent	propulsive,	SIVB Sta.2212, Section C-C ¹¹ , Fig. 1
LUNAR MODULE		
LCG Evaporator (2)	propulsive, .79 in x 5.59 in ¹²	X _{LM} ³⁵⁴ , Section F-F ¹² , Fig. 1
Primary Loop Evaporator	propulsive, 2.0 in x 10.0 in ¹²	X _{LM} ³⁵⁴ , Section F-F ¹² , Fig. 1
EVA Depress. Valve	propulsive, .0014 ft ² equiv. flow area	X _{LM} ^{234.5} , Y _{LM} ^{10.5} , Z _{LM} ^{64.5} ¹²

* Note that superscripts in the Table refer to reference numbers.

Table V. AAP MODULE LIQUID AND GAS OVERBOARD VENTS

DESCRIPTION		LOCATION
MULTIPLE DOCKING ADAPTER		
Waste Mgmt. Vent	propulsive (athru Cluster c.g.), 3.0" dia. ⁸	SIVB Sta. 2037, Section G-G ⁹ , Fig. 1
AIRLOCK MODULE/STS		
EVA Depress. Valve (AM)	propulsive, .75 in ² equiv. flow area, 2.0" dia. ¹⁰	SIVB Sta. 1736, Section J-J ¹ , Fig. 1
Molecular Sieve (STS)	non-propulsive	SIVB Sta. 1845, Section H-H ¹ , Fig. 1
Condensate Dump (STS)	propulsive, 3/16" orifice ¹⁰	SIVB Sta. 1835, Section I-I ¹⁰ , Fig. 1
ORBITAL WORKSHOP		
Interim Urine Dump	propulsive, .210" dia., .033 lb/sec ¹³	SIVB Sta. 1386, Section K-K ¹ , Fig. 1
Urine Dump (LOX Tank)	non-propulsive ¹³	
Fecal Dryer	propulsive, .813" dia. ¹³	SIVB Sta. 1386, Section K-K ¹ , Fig. 1
LBNP Vacuum Source	propulsive, .437" dia. ¹³	SIVB Sta. 1386, Section K-K ¹ , Fig. 1

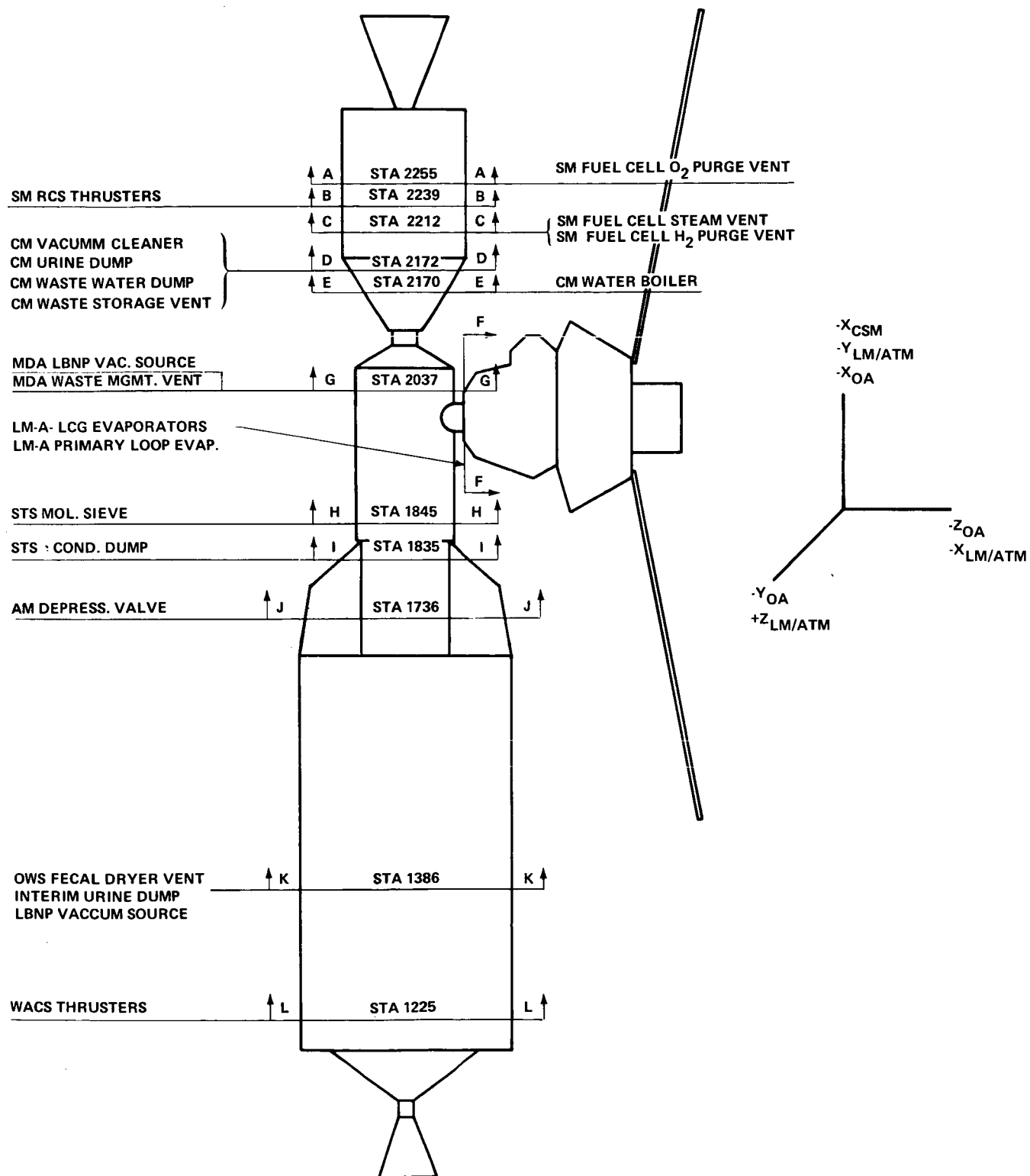
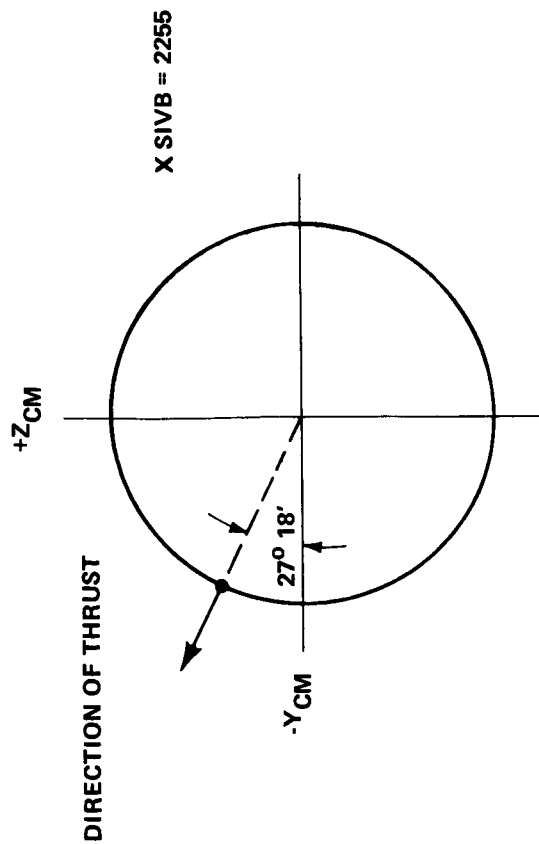
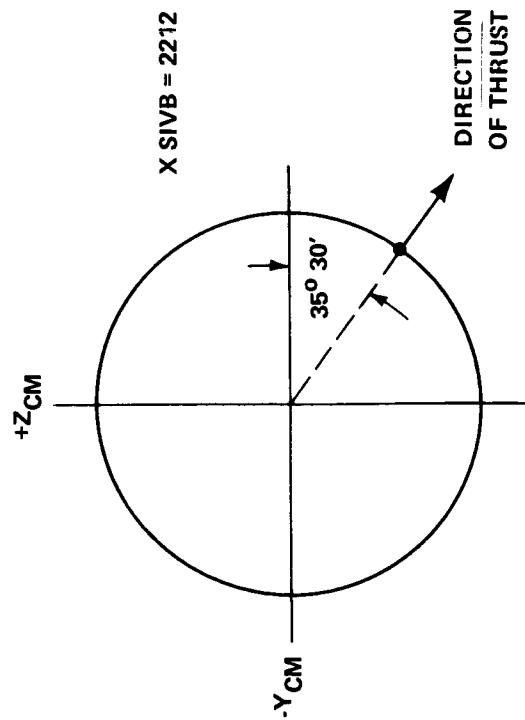


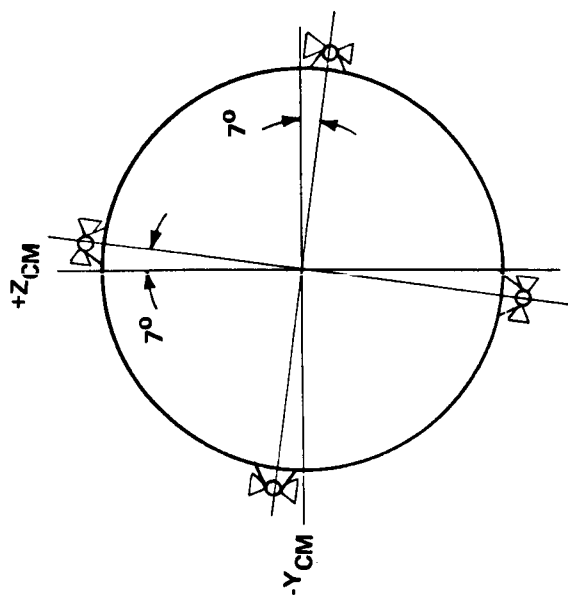
FIGURE 1 - GAS AND LIQUID VENT LOCATIONS IN THE AAP CLUSTER



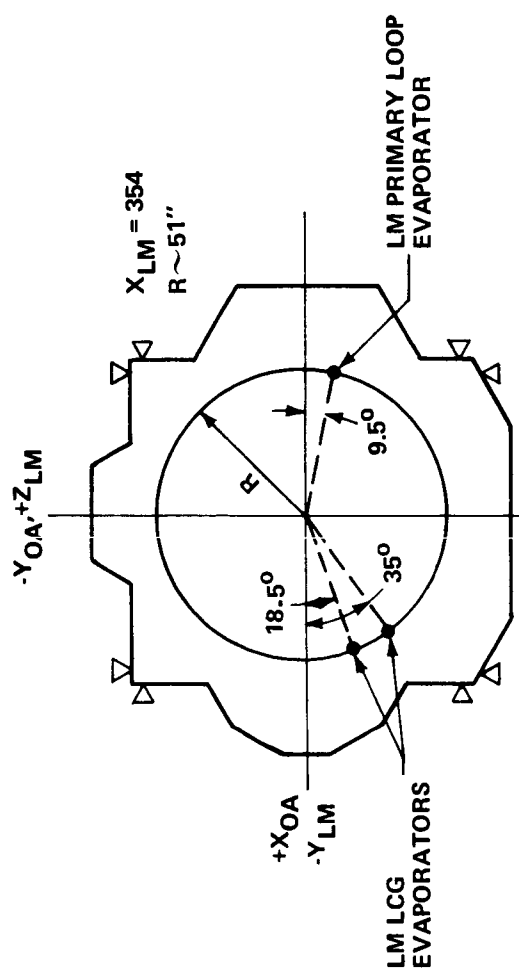
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SM FUEL CELL OXYGEN PURGE VENT



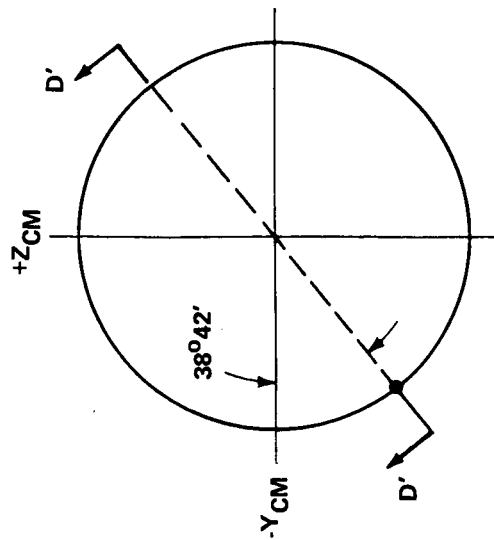
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SM FUEL CELL STEAM VENT & FUEL CELL HYDROGEN PURGE VENT



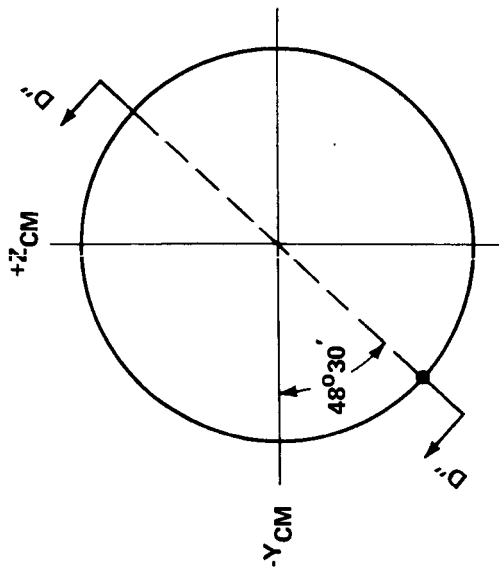
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SM RCS THRUSTERS



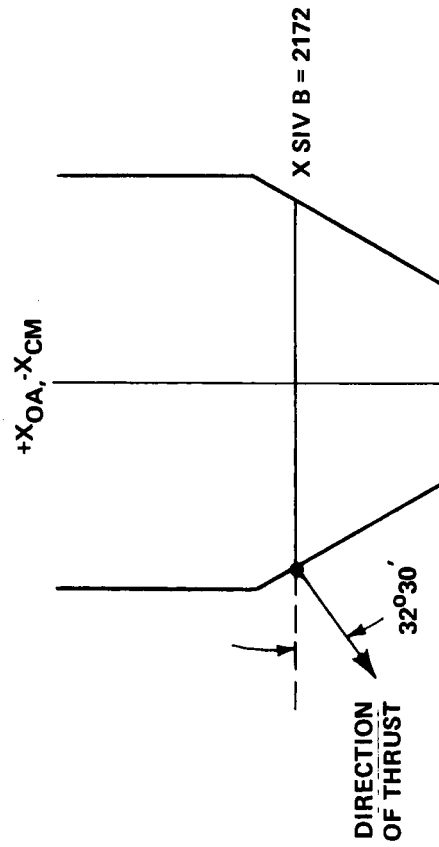
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LM LCG & PRIMARY LOOP EVAPORATORS



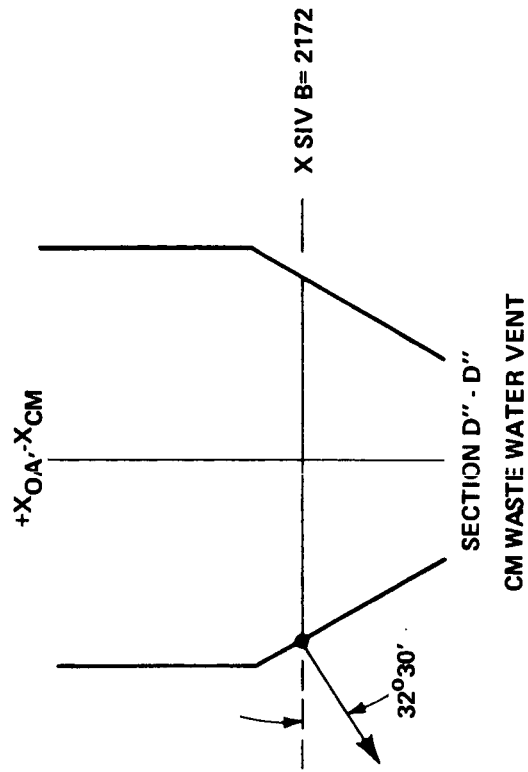
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CM URINE VENT, WASTE STOWAGE
VENT & VACUUM CLEANER VENT.



SECTION D-D
CM WASTE WATER VENT

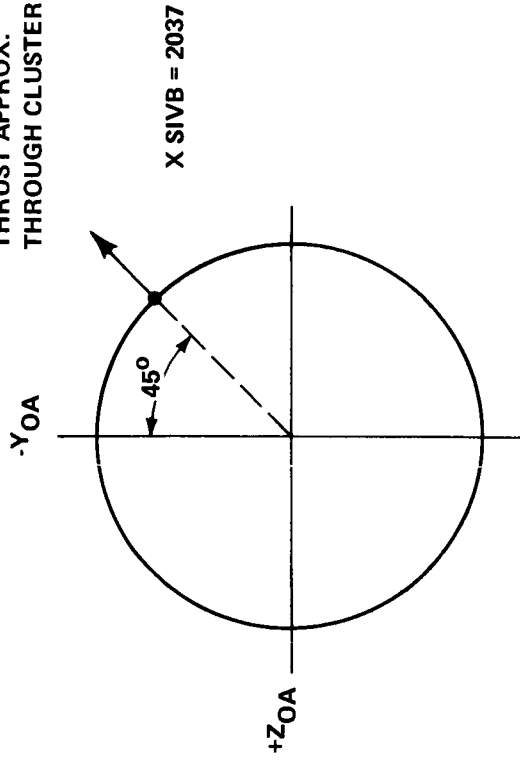


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CM URINE DUMP VENT, WASTE STOWAGE
VENT & VACUUM CLEANER VENT

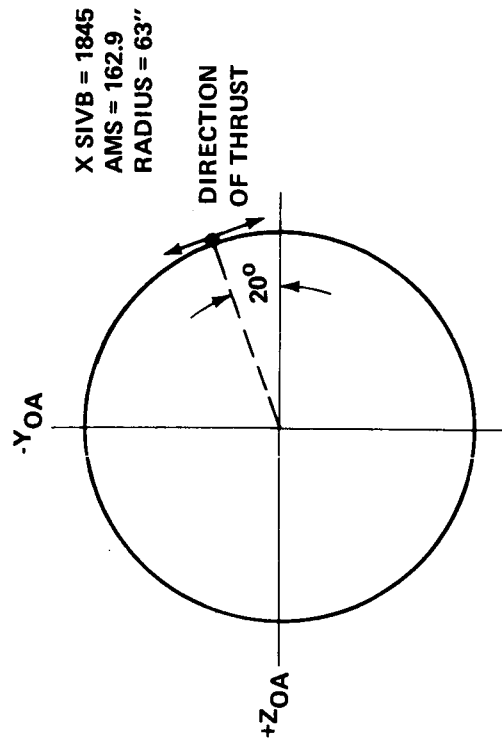


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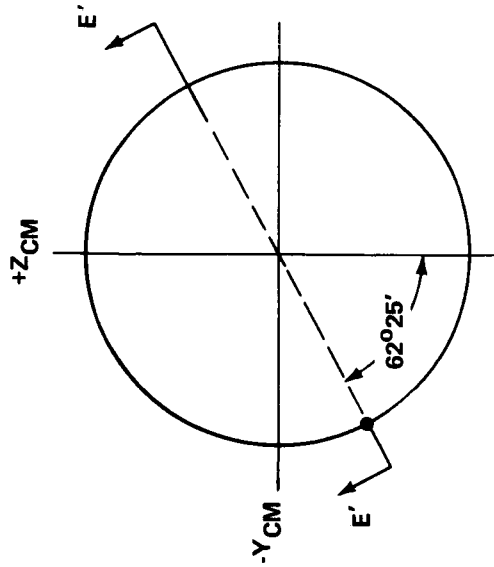
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THROUGH CLUSTER C.G.



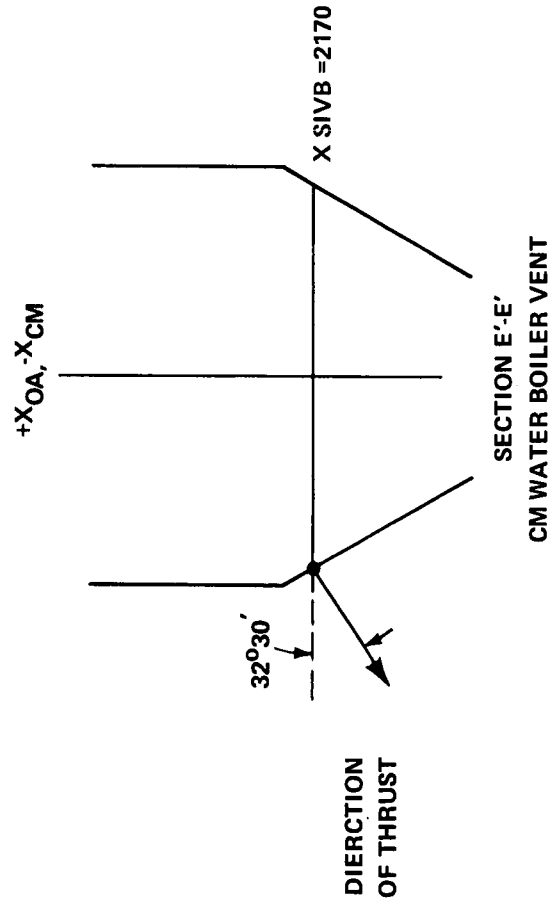
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MDA WASTE MGMT VENT &
LBNP VACUUM SOURCE



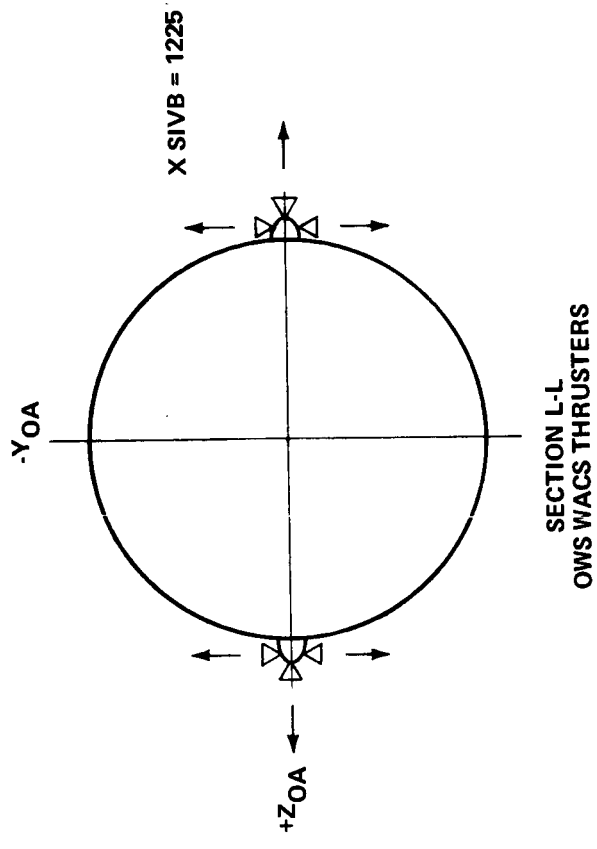
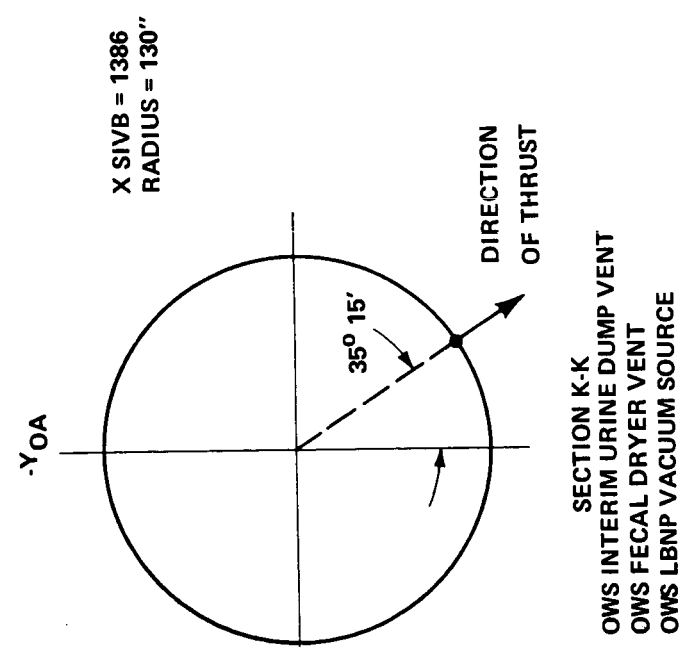
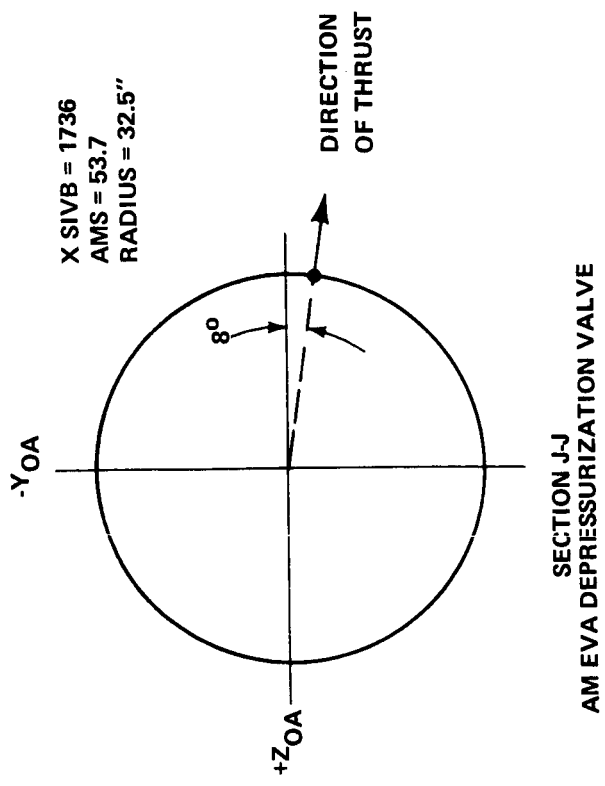
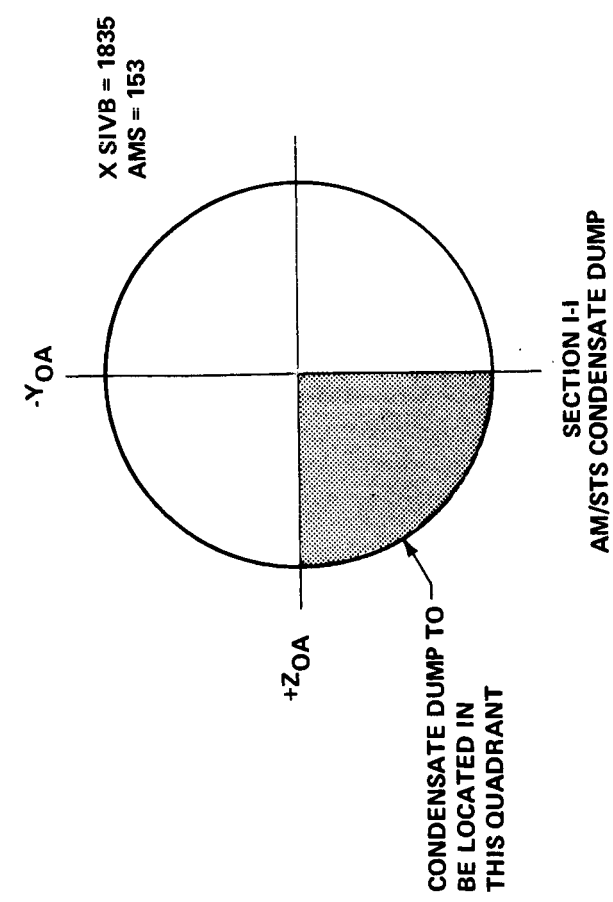
SECTION H-H
STS MOLECULAR SIEVE VENT



SECTION E-E
CM WATER BOILER VENT



SECTION E'-E'
CM WATER BOILER VENT



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11. Personal communication with P. Wingebach, North American Rockwell Corporation, April 17, 1969.
12. Personal communication with R. Renman, I. Victor, and G. Meyer, Grumman Aircraft Engineering Corporation, March 18, 1969.
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BELLCOMM, INC.

Subject: A Compilation of Discharged Fluids
and Fluid Vent Properties for the
AAP Cluster - Case 620

From: J. J. Sakolosky

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H. E. Gartrell/KF
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